Lockheed-Martin ORINCON

Tactical Approach To Computing and Communicating Sonar Performance Uncertainty

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Capturing Uncertainty DRI Final Review

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Philosophical Approach

- Measure what you can (with uncertainties)
- Model what you must.
- Use tactically relevant metrics to measure uncertainty and communicate it.
- NB Coherent TL overestimates the variability experienced in systems that average over space/time/frequency. (predicted location of nulls can’t be trusted)
- Get the mean right, THEN worry about the variability.
- Match the complexity of the environmental parameterization with the degrees of freedom of the acoustic data.
- Provide confidence measure for performance prediction

- SONAR Equation: SE = SL + TL – NL(beam or omni-DI)
  - Detection made when SE - DT(-3 dB) > 0

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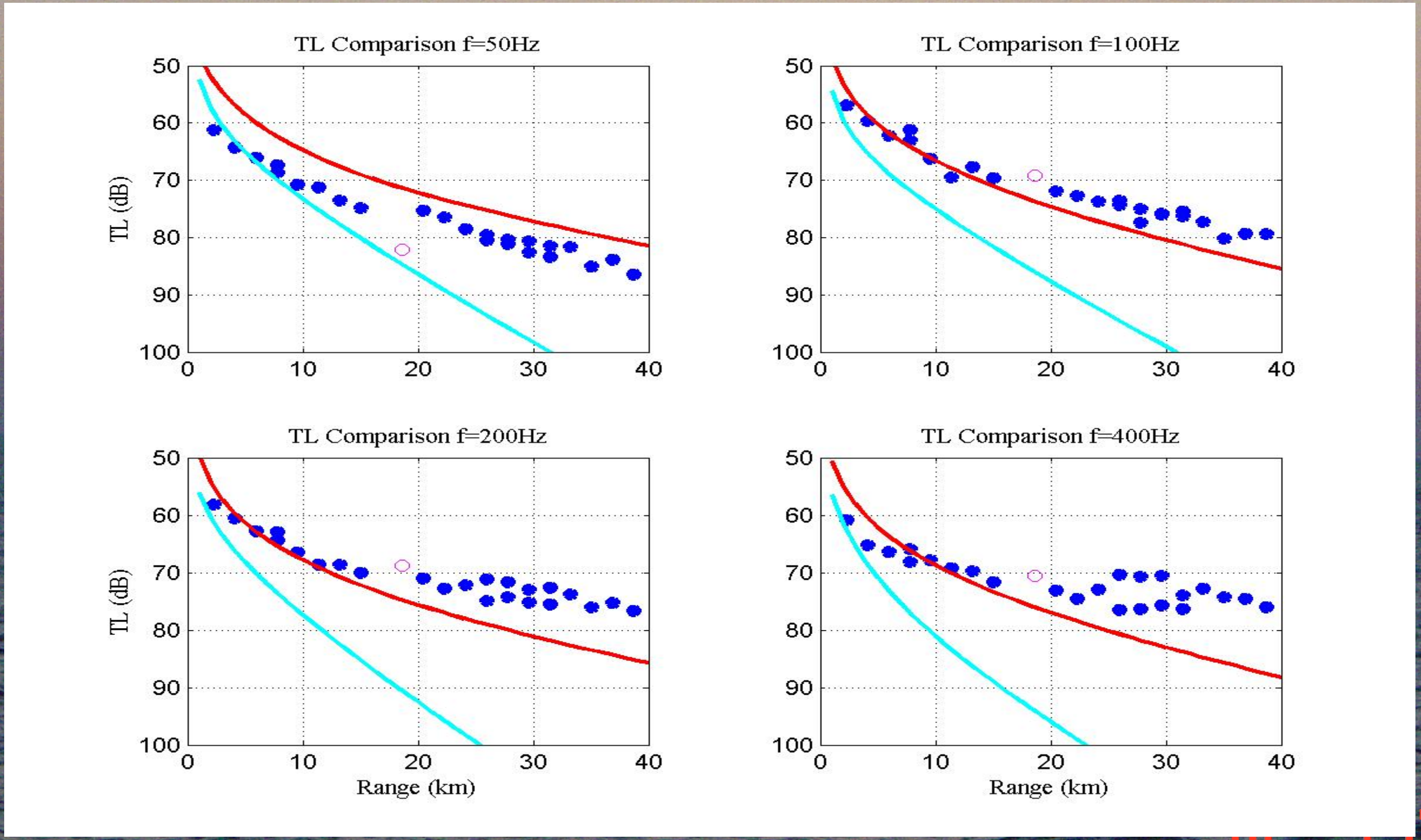
Procedure

1. **Performance Prediction based upon archival environmental data.**
2. **Measure environment with associated uncertainty**
    1. **Ambient Noise measurement**
    2. **Sound Speed Measurements (could be MODAS)**
        1. **Build EOF's and generate random ensemble of sound speed profiles**
    3. **Geo-acoustic Inversion (via GAIT Rapid Geo-acoustic Characterization Algorithm)**
        1. **Perform the inversion multiple on multiple sources and develop statistics.**
3. **Compute statistics of acoustic observables:**
    1. **Incoherent TL vs. range/frequency**
    2. **Coherent TL**
    3. **Time Spread**
    4. **Striation Slope**
4. **Compute detection performance with measured noise, modeled TL uncertainty.**
5. **Communicate the system performance prediction to the operator.**

Database errors in the East China Sea

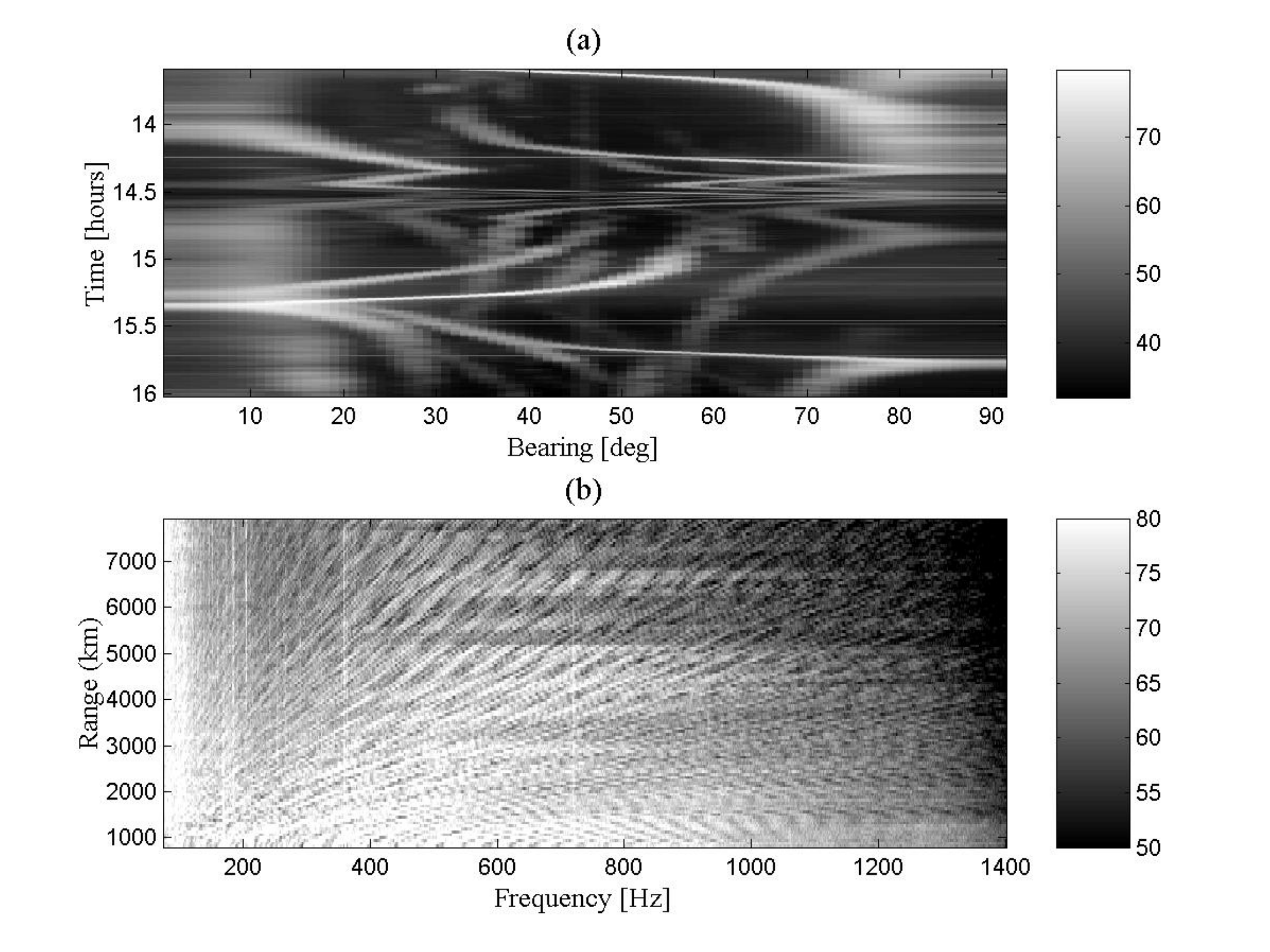


Heaney, K.D., *Active Rapid Geo-acoustic Characterization.* IEEE Journal of Ocean Engineering, 2004. (in review)

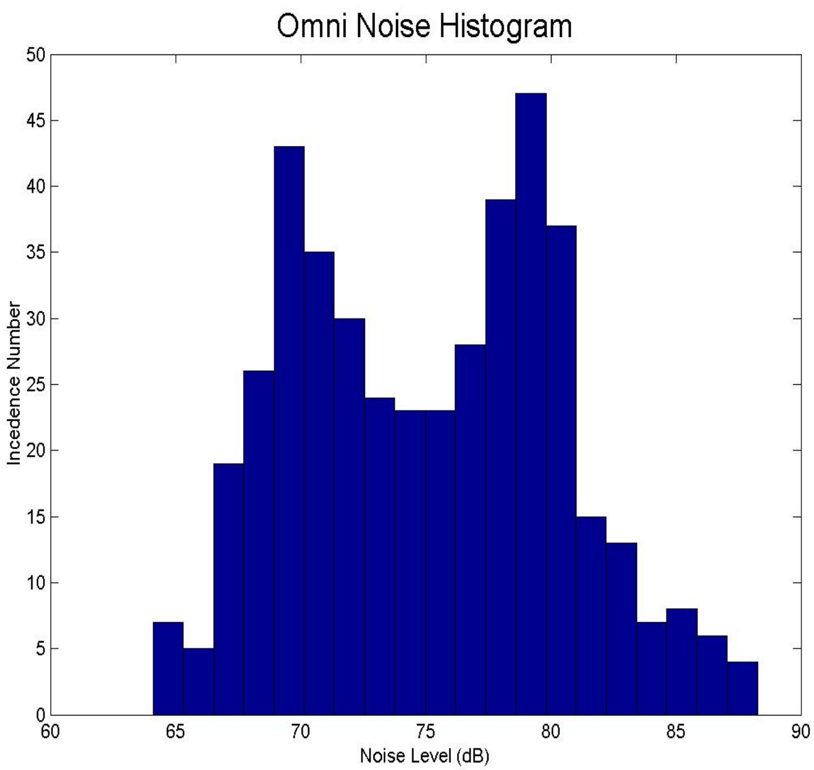
Scenario

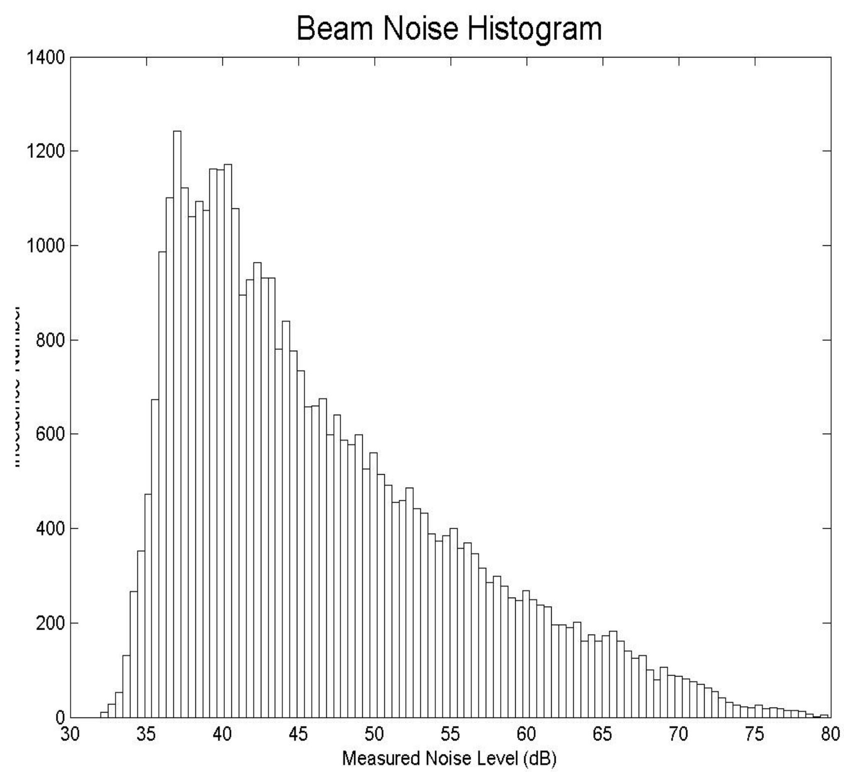
- **Shallow water Mediterranean**
- **Towed line array – passive detection**
- **Dynamic ambient noise field (omni = 78 dB)**
- **Range independent bathymetry.**
- **Downward refracting profile with mild internal waves.**
- **Data taken from BOUNDARY 2003 sea-test conducted by SACLANT (Dr. Peter Neilsen) and SPAWAR (Kevin Heaney)**

Measured Acoustic Data



Ambient Noise (AN) Distributions





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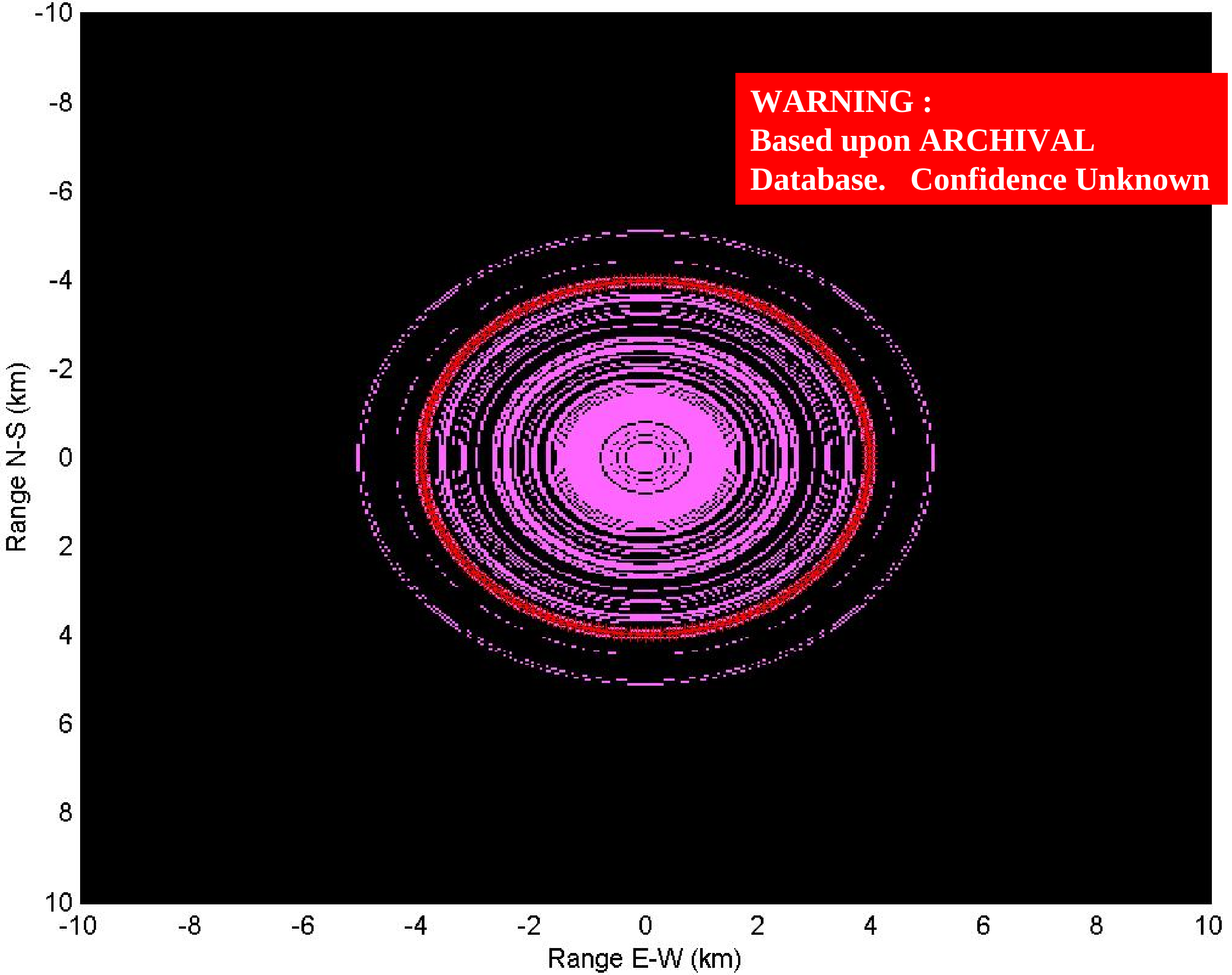
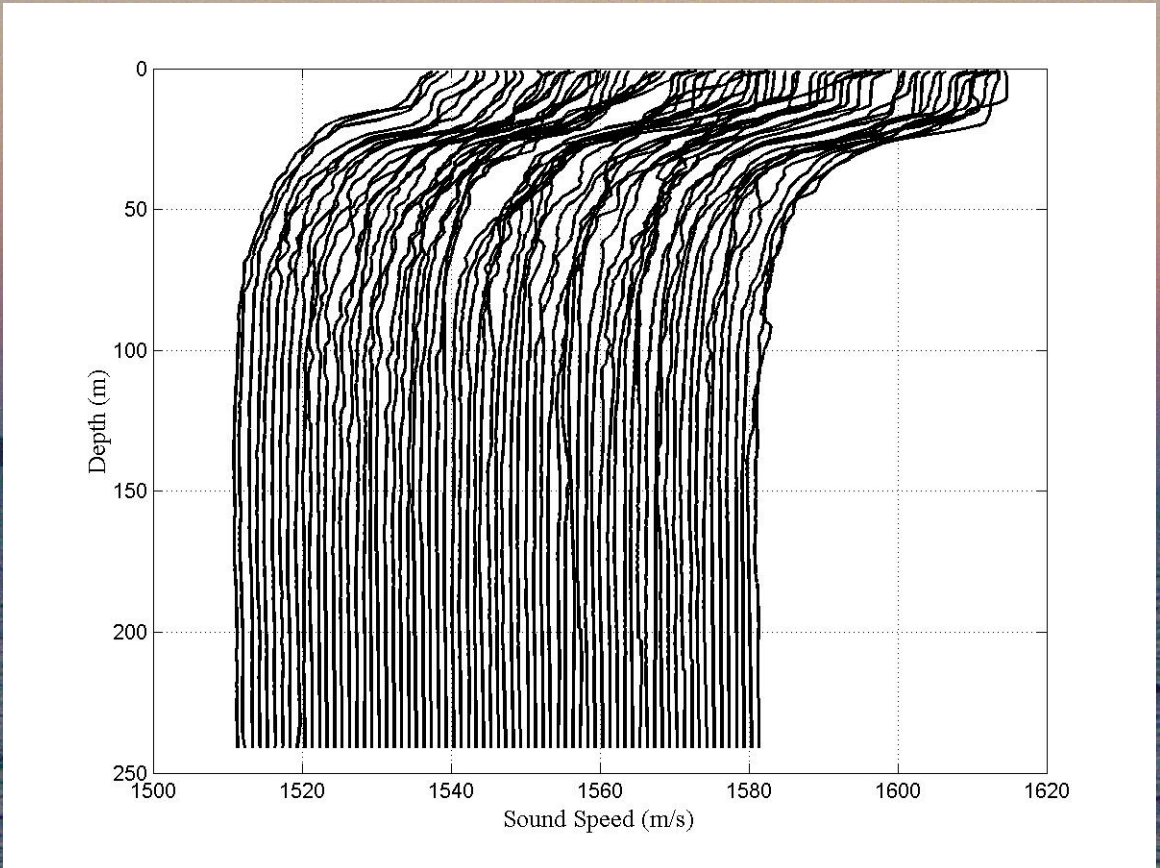
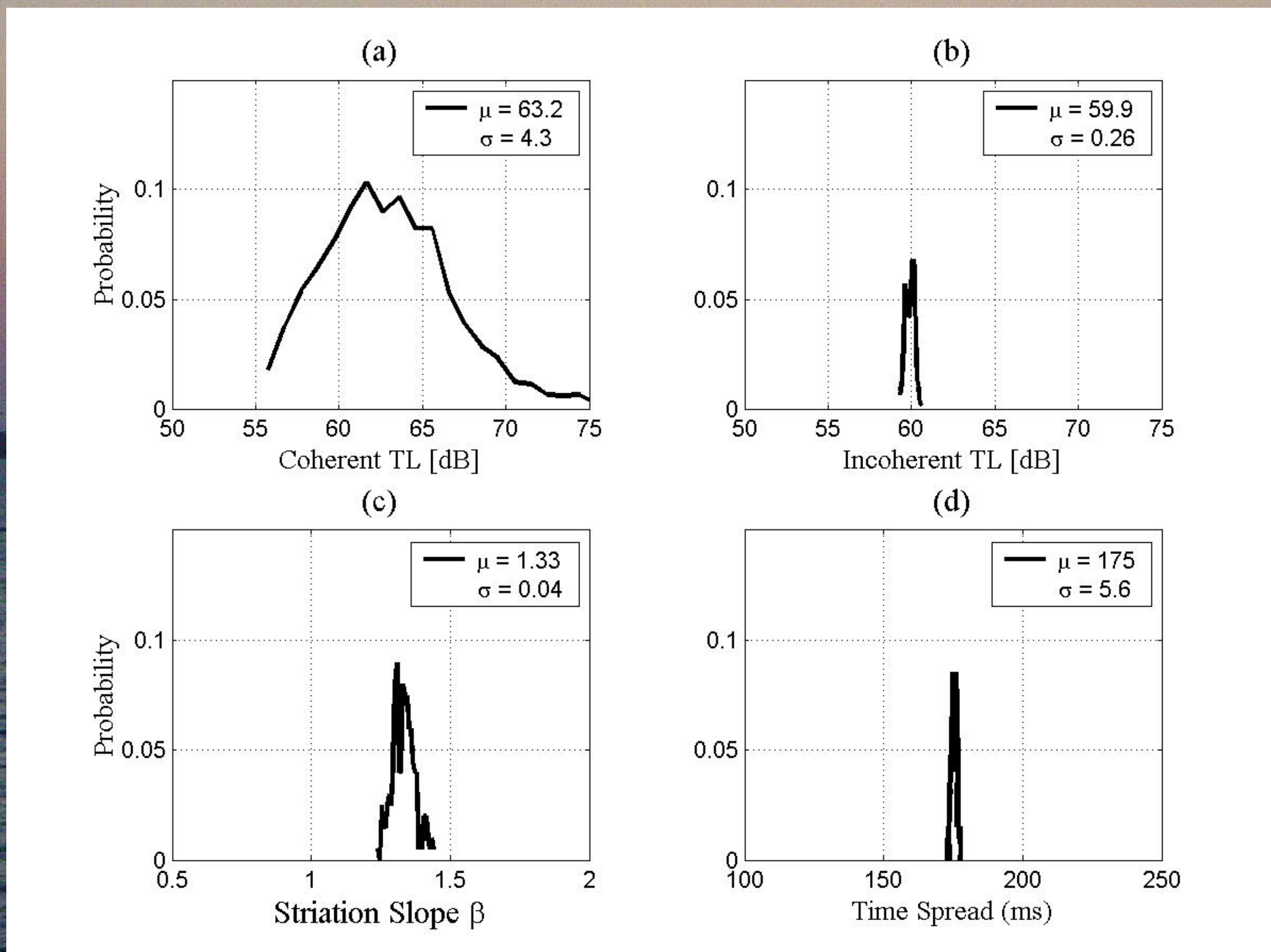
Archival Prediction



Sound Speed Measurements



Acoustic Observable Distributions - Sound Speed Variability



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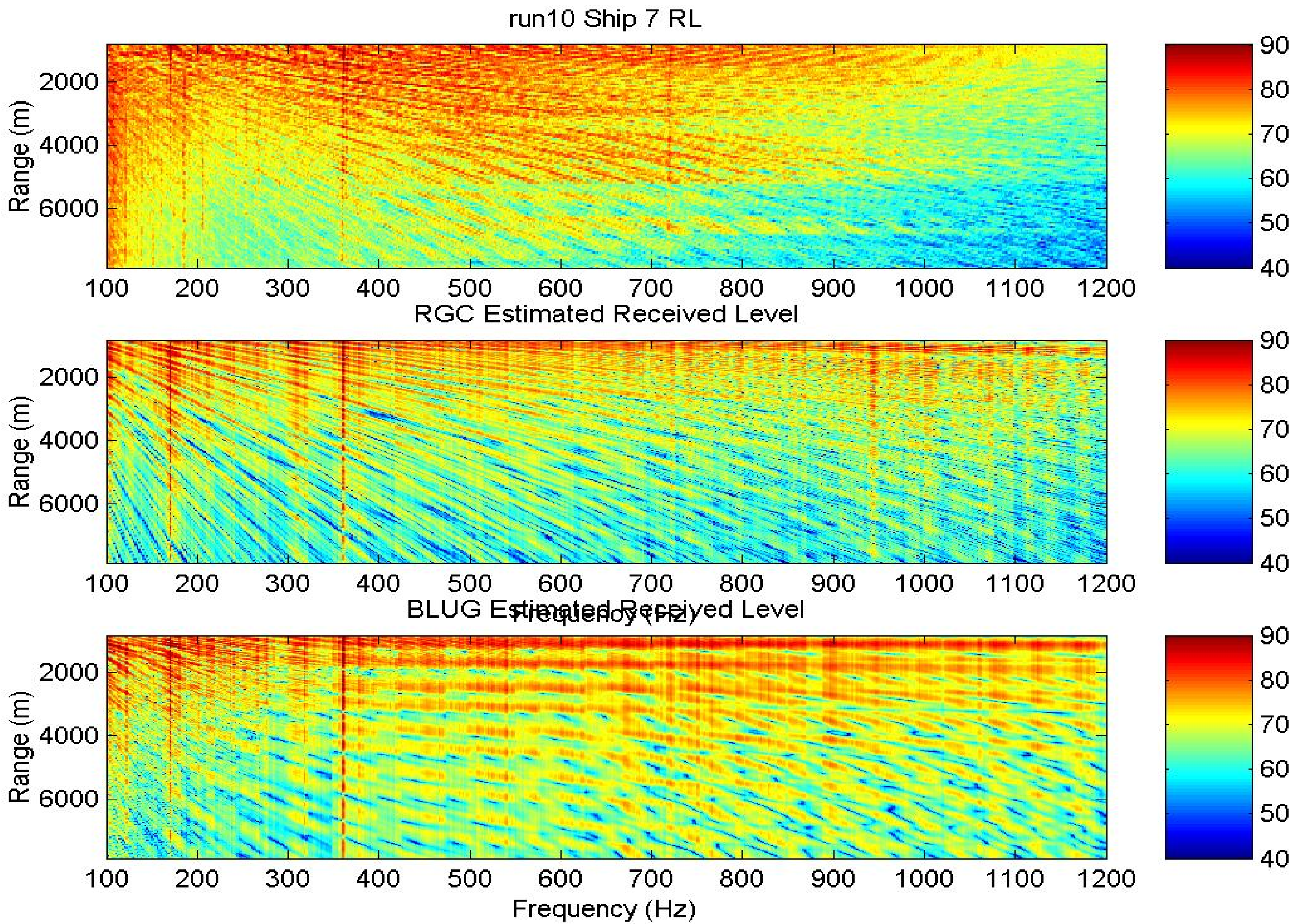
Rapid Geo-acoustic Characterization

- **Measure acoustic observables from measured striations**
  - **Striation slope, striation spacing, RL slope vs range.**
- **Compute the observables for simple single homogeneous sediment with two free parameters (Cp, H)**
- **Determine the optimal environment.**
- **Results:**
  - **<Cp> = 1565 m/s;** σ_{Cp} **= 15 m/s**
  - **<H> = 20 m;** σ_{H} **= 3m**

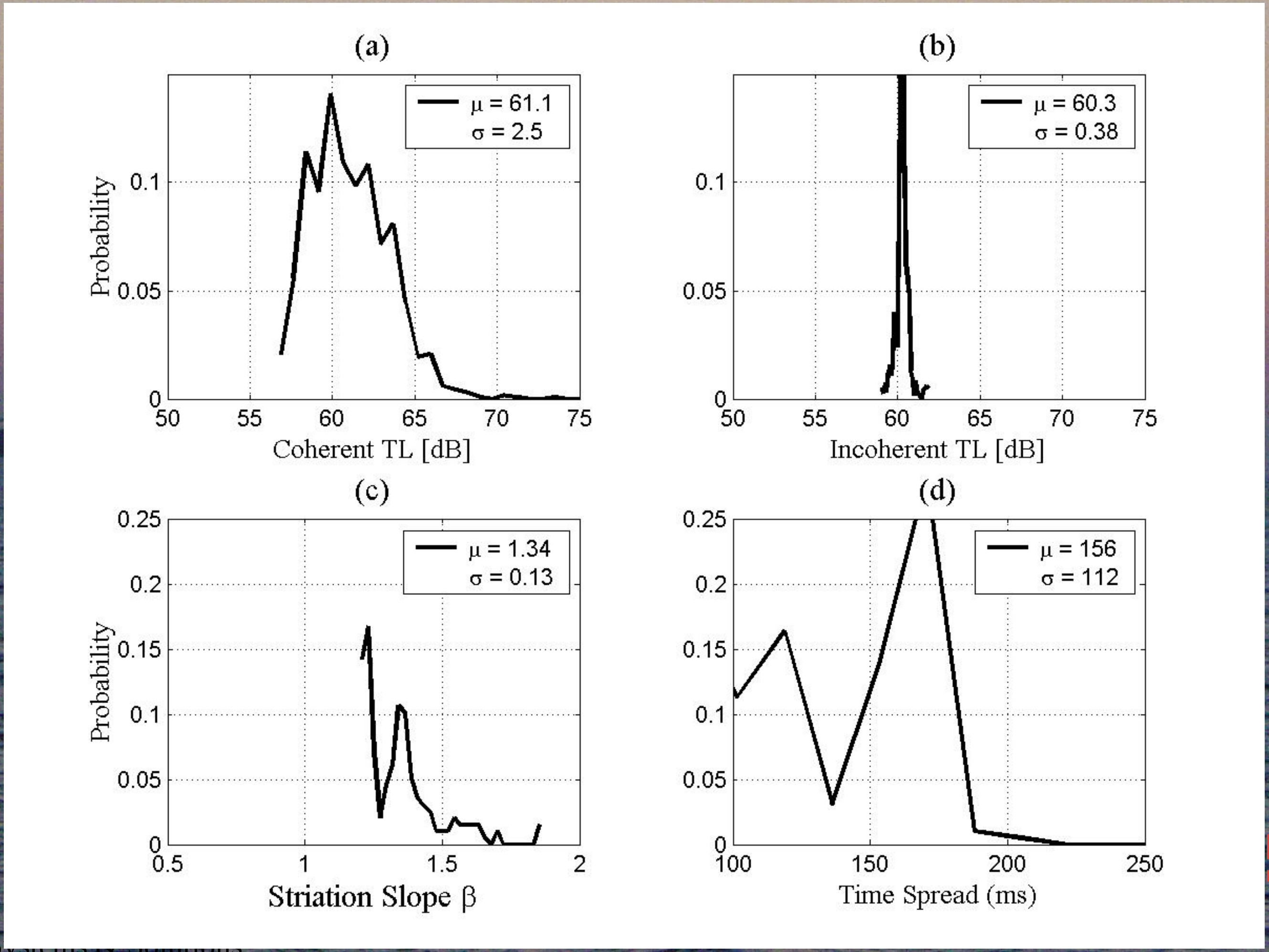
Heaney, K.D., *Rapid Geoacoustic Characterization Using a Ship of Opportunity.* IEEE Journal of Ocean Engineering**, 2004. 29**(1): p. 88-99.

Heaney, K.D., *Rapid Geoacoustic Characterization: Applied to Range-Dependent Environments.* IEEE Journal of Ocean Engineering, 2004. **29**(1): p. 43-50.

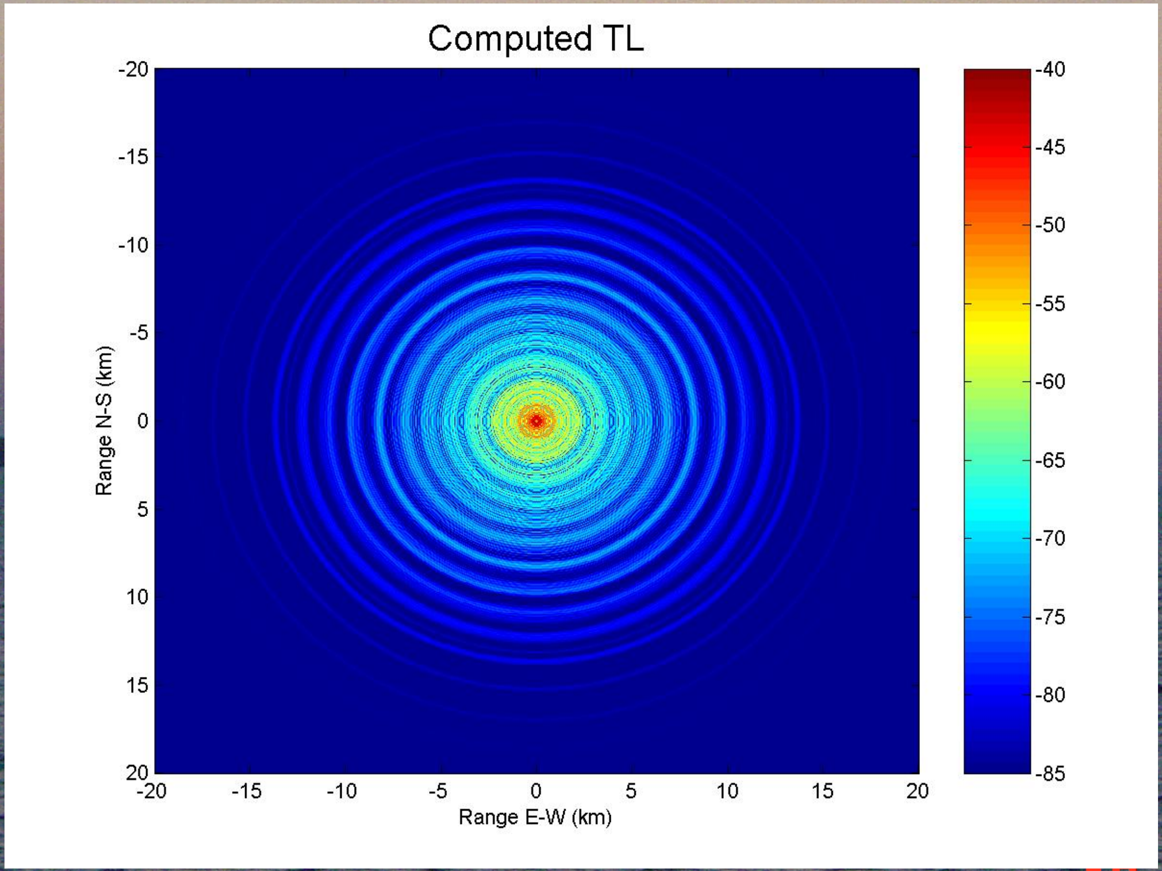
RGC results


run10 Ship 7 RL
RGC Estimated Received Level
BLUG Estimated Received Level
Range (m)
2000
4000
6000
100
200
300
400
500
600
700
800
900
1000
1100
1200
Frequency (Hz)
90
80
70
60
50
40

Acoustic Observable Distributions
Geo-Acoustic Variability



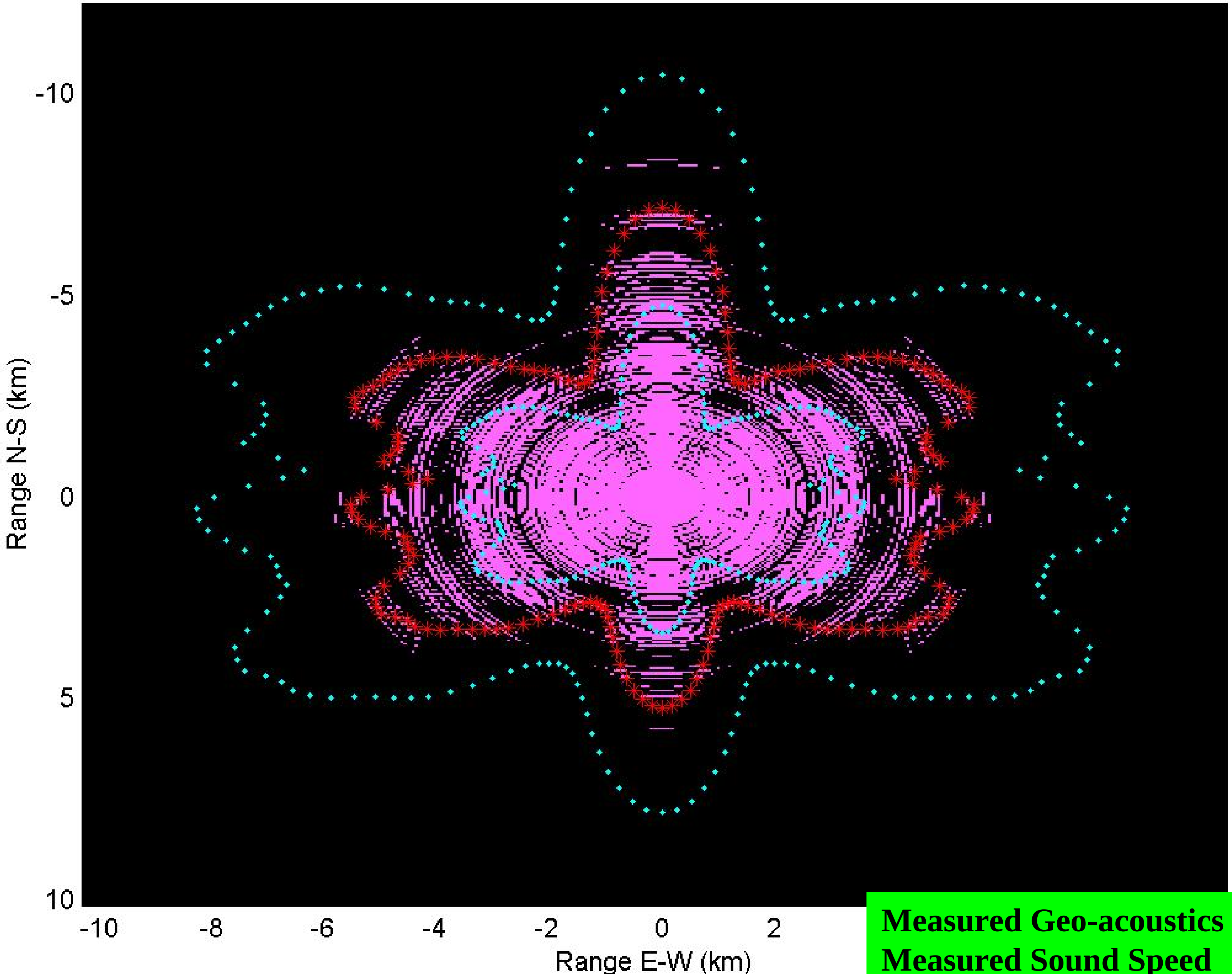
Computed Transmission Loss



Combine modeled TL, measured AN, estimated SL, array performance

Average Detection Performance

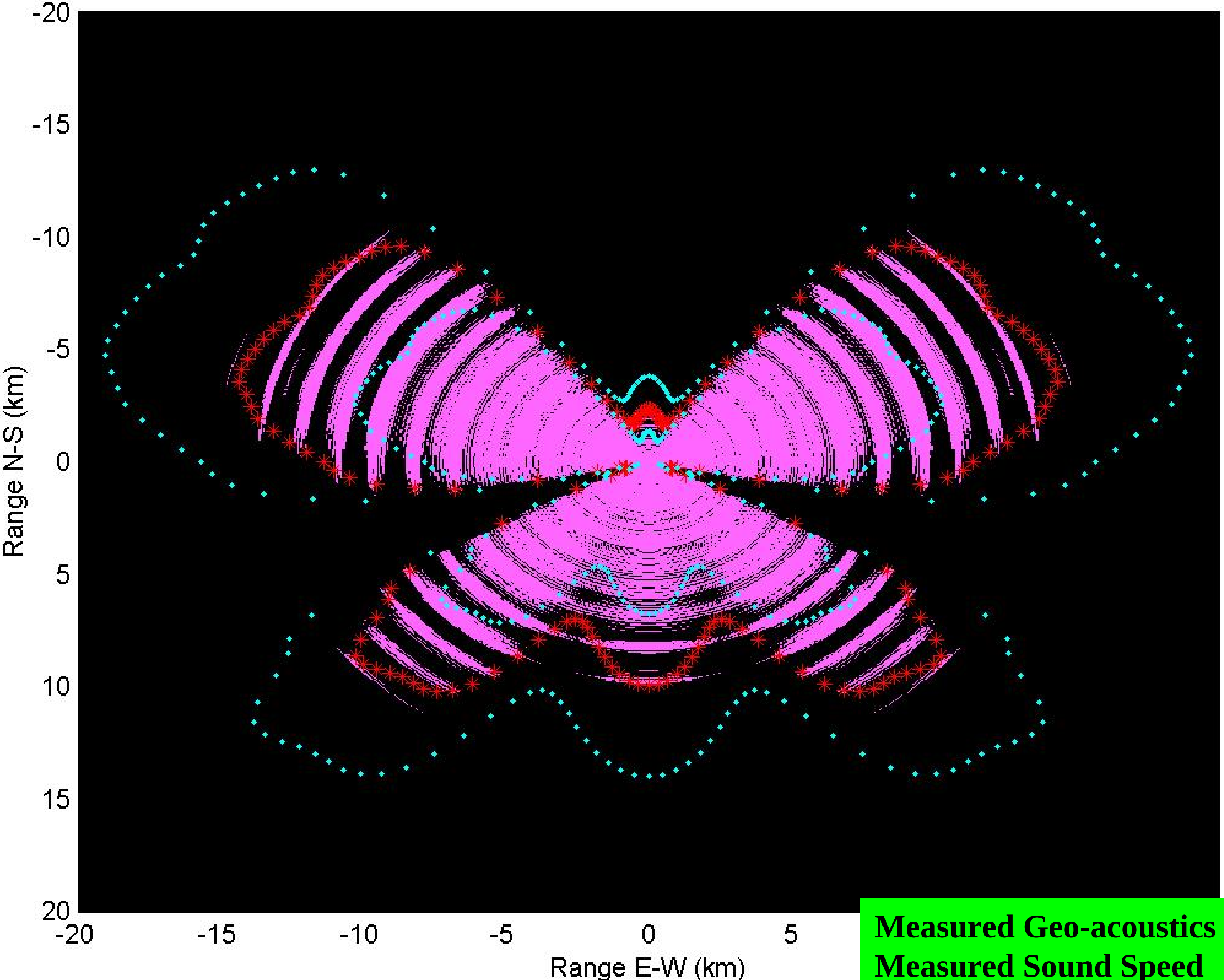
$\sigma = 4.97$**dB**



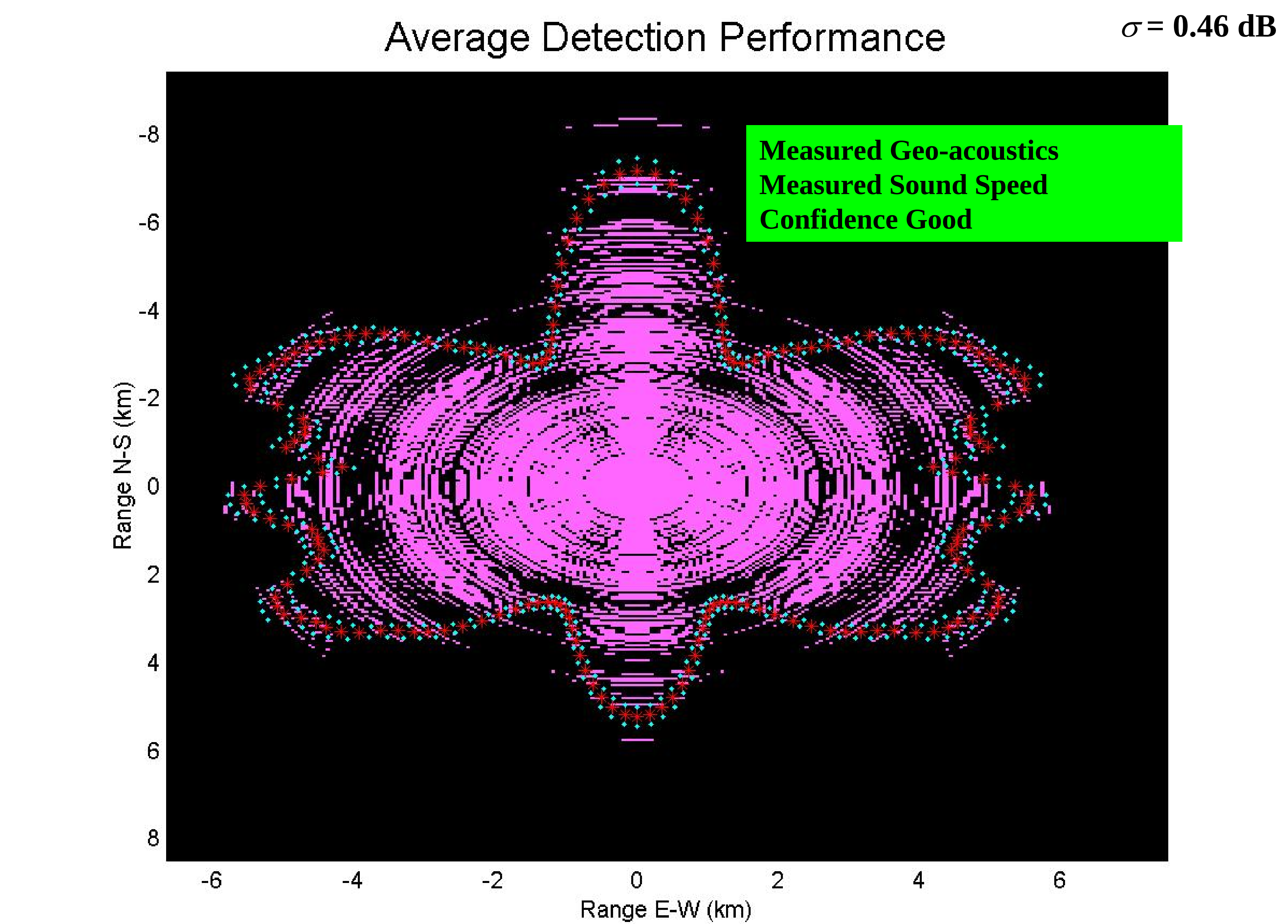
Measured Geo-acoustics
Measured Sound Speed
Confidence Good

Instantaneous Detection Performance

$\sigma = 4.97$dB

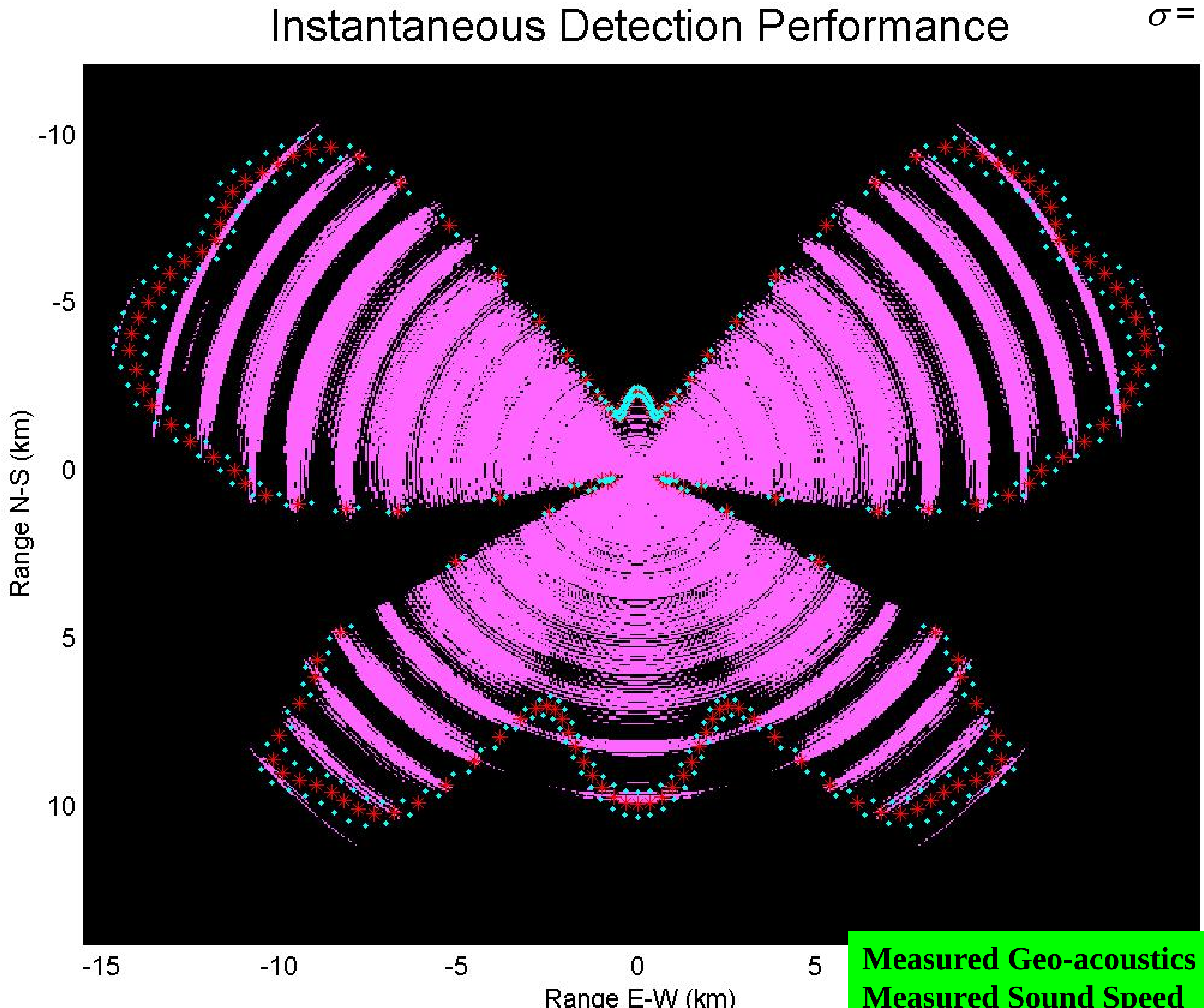


Measured Geo-acoustics
Measured Sound Speed
Confidence Good



Average Detection Performance
σ = 0.46 dB
Measured Geo-acoustics
Measured Sound Speed
Confidence Good
-8
-6
-4
-2
0
2
4
6
8
Range N-S (km)
-6
-4
-2
0
2
4
6
Range E-W (km)

$\sigma = 0.46$ dB



Measured Geo-acoustics
Measured Sound Speed
Confidence Good

Conclusion

- **Using a combination of measurements, inversions and modeling we have an approach to communicate the instantaneous (as well as time-averaged) uncertainty and confidence to the operator.**
- **In this benign environment, SVP and geo-acoustic variability are on the order of 0.5 dB (at 4 km) and detection range variability is on the order of 800m (at 7km).**
- **The ambient noise field is significantly more dynamic than the TL uncertainty.**
- **Coherent TL statistics can greatly over-estimate the system performance uncertainty.**

Heaney and Cox,, *A Tactical Approach to Environmental Uncertainty and Sensitivity.* IEEE Journal of Ocean Engineering**, 2004. submitted**